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# METHOD OF REGENERATING FILTER FABRIC

## AND REGENERATED FILTER FABRIC

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

This invention relates to a method for regenerating a used filter fabric and a regenerated filter fabric obtained by regenerating a used filter fabric.

#### 2. Description of the Related Art

Many of conventional filter fabrics have practically been disposed after use because of time and money of the recycling work. However, filter fabrics sometimes bear harmful components such as dioxin in form of dust through their utilization. Therefore, an incineration disposal or a landfill disposal costs time and money and is not environment-friendly in terms of global environmental preservation. In such a situation, it has strongly been desired to develop efficient recycling and reuse of a used filter fabric.

As a conventional recycling technique of a filter fabric, there is a regeneration method of washing out adhering dust with water such as spraying flowing water on the surface of a used filter fabric or a washing chemical agent (see e.g. reference to Japanese Patent Laid-Open (JP-A) No. 2003-103128).

However, such a method of washing with water only separates

a portion of dust adhering to the surface layer of component fibers resulting in a lot of dust adhering to the inside being remained. Therefore, a filter fabric regenerated by water washing has a much higher pressure loss than a new one. For example, according to the test results shown in Table 1, the initial pressure loss is 70 Pa for a new one while it is 106 Pa for the regenerated one. Like this, it has been impossible to obtain an initial pressure loss as low as that of a new one after regeneration.

Further, attributed to the remaining of the dust in the inside, dust tends to be accumulated in the inside. Therefore, the filter fabric regenerated by water washing shows very quick increase of the pressure loss and is more likely to cause clogging. For example, according to the test results shown in Table 1, although backwashing is carried out frequently to fix the clogging, the pressure loss after 8 hours use is 302 Pa while it is 122 Pa for a new one. As described, after regeneration, it has been impossible to obtain a lifetime as long as that of a new one.

Further, since the clogging is easily occurred, frequent backwashing for shaking off the dust by blowing compressed air in the inversed direction to the air filtration direction is required in order to lower the pressure loss. However, at the time of backwashing, since the twisting of fibers is weakened for a moment, the once collected dust (in the inside of the filter

fabric) flows out toward the outlet due to the flow of dust-containing air. For example, it is found from the test results shown in Table 1 that the accumulative outlet dust concentration is  $2.15 \text{ mg/m}^3$  after 8 hours use, while it is  $1.173 \text{ mg/m}^3$  for a new one. As described, if backwashing is carried out frequently, the outlet dust concentration is increased and thus it has been impossible to achieve a dust collection efficiency as high as that of a new one after regeneration.

Further, since the twisting of the fibers is weakened due to not only the high water pressure brought to the surface layer of the filter fabric but also the frequent backwashing, the strength and elongation of the regenerated filter fabric is considerably deteriorated as compared with a new one.

There have been regenerable filter fabrics coated with a thermofusible binder resin or a solvent-soluble binder resin as another regeneration technique of a filter fabric (see e.g. reference to JP-A Nos. 9-253432 and 2001-336054). In this regeneration technique, by a heat-treatment of a used fiber fabric or an immersion treatment of a used fiber fabric in a solvent, dust can be easily and highly efficiently separated from the filter fabric with melting the binder resin. Accordingly, this technique is to inhibit the increase of the pressure loss and the time to the same level as those of a new filter fabric and at the same time secure the filtering efficiency and the strength of the regenerated filter fabric by preventing

the damages on component fibers.

However, since the regeneration method involves heat melting or chemical reaction, the filter fabric cannot be used at a high temperature or in chemically severe environments and thus only limited application is possible.

Further, since a costly special binder resin is applied by special coating process and separated by special separation process at the time of regeneration, the production cost is high and the filter fabric is not economical. In addition, even if dust can be separated from fibers at the time of regenerating the fibers, it is still difficult to separate the dust from the binder resin and regenerate the binder resin itself. Therefore, the regenerated filter fabric is inferior for the practical use in terms of the cost.

In view of the above-mentioned state of the art, it is an object of the invention to provide an economical and practically applicable regeneration method for a used filter fabric by which the pressure loss and the filtering efficiency are kept as good as those of a new filter fabric even after regeneration and by which a regenerated filter fabric is usable even at a high temperature or in chemically severe environments without limiting its application and it is also an object of the present invention to provide an economical regenerated filter fabric by this method.

Patent Document 1: Japanese Patent Laid-Open No. 2003-103128

Patent Document 2: Japanese Patent Laid-Open No. 9-253432

Patent Document 3: Japanese Patent Laid-Open No. 2001-336054

#### SUMMARY OF THE INVENTION

To solve the above-mentioned problems, the invention employs the following means (1) to (12).

(1) A regeneration method of a filter fabric of the invention involves at least fibrillation treatment for fibrillating a used filter fabric and nonwoven treatment for producing a nonwoven fabric from the fibers obtained by the fibrillation treatment.

The fibrillation treatment of the invention here means treatment for fibrillating a used filter fabric to individual single fiber elements. Also, the nonwoven treatment of the invention means treatment for producing a nonwoven fabric in a desired shape made of mainly the fibrillated fibers held together by interlocking or fixing and bonding.

The above-mentioned regeneration method can reliably separate the dust adhering between the fibers, regardless of whether the dust adheres to the surface or inside of the component fibers of the pre-regenerated filter fabric, since the regeneration is conducted by single fiber basis because of the fibrillation.

Consequently, the dust adhering to the inside of the component fibers, which cannot be separated by the above-mentioned water washing method, can be separated, so that

the increase of the pressure loss and the time and filtering efficiency can be kept approximately same as those of a new filter fabric even after regeneration. Further, twisting of the component fibers is not weakened unlike the case of water washing and the strength almost same as that of a new filter fabric can be secured.

Further, the nonwoven treatment strengthens the twisting of the fibers and as compared with the case of the above-mentioned water washing method, strength approximately same as that of a new filter fabric can be obtained.

Since the regeneration method by the fibrillation treatment and the nonwoven treatment of the fibrillated fibers can be carried out without using a thermally fusible or chemically reactive resin such as a binder resin, the filter fabric obtained by this method can be used at a high temperature or in chemically severe environments and its application is not limited unlike a filter fabric using the above-mentioned binder resin.

Further, since neither the above-mentioned costly binder resin is used nor the above-mentioned special coating process is needed, as compared with a filter fabric using the binder resin, the regeneration method of the present invention is economical and highly practically applicable.

(2) Alternatively, the regeneration method of a filter fabric of the invention may involve powder dust separation treatment for separating the powder dust adhering to the fibers obtained

by the fibrillation treatment before the nonwoven treatment. That is, the regeneration method of a filter fabric may involve at least fibrillation treatment for fibrillating a used filter fabric, powder dust separation treatment for separating the powder dust adhering to the fibrillated fibers, and nonwoven treatment for producing a nonwoven fabric from the fibers obtained after the powder dust separation treatment.

Accordingly, more dust can be separated by carrying out the powder dust separation treatment after the fibrillation to give an excellent airflow property and filtering efficiency.

Further, because of the nonwoven treatment, the twisting of the fibers is further strengthened and therefore, the strength is closer to that of a new filter fabric as compared with the case of the above-mentioned water washing method.

(3) In the above-mentioned regeneration method of a filter fabric of the invention, the filter fabric is preferably fibrillated by an automatic fibrillation apparatus in the fibrillation treatment in terms of efficient regeneration.

Accordingly, dust can easily be separated by the mechanical automatic fibrillation and consequently it makes the regeneration easy and economical.

(4) In the above-mentioned regeneration method of a filter fabric of the invention, the used filter fabric is preferably a filter fabric used in a manner that adhesion of dioxin to the filter fabric is prevented by adding a chemical agent capable

of decomposing both dioxin and dioxin origin substances.

Herein, in the invention, dioxin origin substances mean dioxin precursors such as chlorophenol, chlorobenzene, and the like.

Accordingly, the added chemical agent decomposes dioxin and dioxin origin substances contained in dust-containing air during the use of the filter fabric not becoming the used filter fabric, so that the dioxin concentration itself is lowered. Consequently, the absolute number of dioxin in the dust to be brought into contact with the filter fabric is suppressed and adhesion of dioxin to the filter fabric is inhibited. In such a manner, a filter fabric in which the dioxin adhesion to the fibers is inhibited is fibrillated as a used filter fabric, so that a regenerated filter fabric scarcely bearing dioxin can be obtained.

Accordingly, even a used filter fabric used in dioxin-containing atmosphere, which has been difficult to be regenerated conventionally, can be used as a raw material for regeneration. Consequently, the regeneration method can considerably save the time and money required for the disposition procedure of the filter fabric bearing dioxin and thus can be economical and highly practically applicable.

(5) In the above-mentioned regeneration method of a filter fabric, the used filter fabric is preferable to be mainly made up of PTFE fibers.



Accordingly, it is enabled to obtain a regenerated filter fabric excellent in the strength and filtering efficiency and also excellent in chemical resistance and heat resistance.

(6) Alternatively, in the regeneration method of the filter fabric, the used filter fabric is preferable to contain at least PTFE fibers and inorganic fibers.

Accordingly, the regenerated filter fabric is to contain fibrillated inorganic fibers and thus the filtering efficiency of the regenerated filter fabric will be improved. Further, the time and money for separating the inorganic fibers prior to the fibrillation treatment can be saved and the regenerated filter fabric containing inorganic fibers can efficiently be obtained.

(7) The regenerated filter fabric of the invention is characterized by including at least a dust collection layer mainly made up of the fibrillated fibers obtained by fibrillating the used filter fabric.

(8) Also, the regenerated filter fabric may include a base cloth to which the dust collection layer is fixed. That is, the regenerated filter fabric may include at least the dust collection layer formed by fibrillating the used filter fabric and the base cloth to which the dust collection layer is fixed.

Accordingly, the filter fabric becomes stronger because of the base cloth and the twisting strength of the component fibers can be kept as high as that of a new filter fabric even

if the filter fabric is backwashed during its use.

(9) Further, the above-mentioned regenerated filter fabric may include the dust collection layer which is made up of the fibrillated fibers mixed with auxiliary fibers.

That is, the regenerated filter fabric may include at least the dust collection layer formed by mixing the fibers obtained by fibrillating a used filter fabric with auxiliary fibers, or the regenerated filter fabric may include at least the dust collection layer formed by mixing the fibers obtained by fibrillating a used filter fabric with auxiliary fibers and the base cloth for fixing the dust collection layer.

Accordingly, addition of the auxiliary fibers makes it possible to give the regenerated filter fabric with high strength and elongation.

(10) With respect to the above-mentioned regenerated filter fabric, the dust collection layer may be formed by the nonwoven fabric produced from the fibers which make up itself (the dust collection layer) by nonwoven treatment.

That is, the dust collection layer may be formed by a nonwoven fabric produced from the fibers obtained by fibrillating the used filter fabric, or the dust collection layer may be formed by a nonwoven fabric produced from the mixed fibers of the fibers obtained by fibrillating the used filter fabric and the auxiliary fibers.

(11) With respect to the above-mentioned regenerated filter

fabric, the used filter fabric is preferable to be mainly made up of PTFE fibers.

(12) Alternatively, with respect to the above-mentioned regenerated filter fabric, the used filter fabric is preferable to contain at least PTFE fibers and inorganic fibers.

It is made possible to provide an economical and practically applicable regeneration method for a used filter fabric by which the pressure loss and the filtering efficiency are kept as good as those of a new filter fabric even after regeneration and by which a regenerated filter usable even at a high temperature or in chemically severe environments without limiting its application and also provide a regenerated filter fabric obtained by this method.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow chart showing an embodiment of a regeneration method of a filter fabric of the present invention;

Fig. 2 is an electron microscopic photograph of a regenerated filter fabric according to an embodiment of the present invention; and

Fig. 3 is an electron microscopic photograph of a new filter fabric.

#### BEST MODE OF THE EMBODIMENTS OF THE INVENTION

Hereinafter, the constitution of the invention will be

described in detail with reference to drawings and photographs for substituting drawings as an embodiment. Fig. 1 is a flow chart of a regeneration method of an embodiment of the invention and Fig. 2 is an electron microscopic photograph magnified at a magnification of 1000 times showing the fiber state fibrillated by the fibrillation treatment of the invention. Fig. 3 is an electron microscopic photograph magnified at a magnification of 1000 times showing the fiber which is not subjected to the fibrillation treatment for comparison with that shown in Fig. 2.

A filter fabric or a regenerated filter fabric used in this invention is a filter fabric to be employed for collecting powder. Particularly in the embodiments described below, the filter fabric is fixed in a filter dust collection apparatus for filtering and collecting dust of an incinerator flue gas discharged out of an incinerator in incineration facilities and used for filtering and collecting dust in form of a powder containing harmful dust such as dioxin and heavy metals at a high temperature, that is 150°C or higher, in ambient environments.

The harmful dust means substances harmful in terms of environment preservation and health hygiene among the dust filtered and collected as powder dust and for example, substances regulated and limited in the discharge amount to the environments and the allowable intake in human body by official organizations

and required to undergo scattering prevention treatment at the time of disposition.

Particularly, dioxin is generally evaluated as highly toxic substance in the harmful dust and it is not only regulated according to the ambient environmental quality standard but also its pollution monitoring and removal methods are specified. Conventionally, a filter fabric used in dioxin-polluted environments has been entirely subjected to landfill disposal since its efficient recycling has been difficult. On the contrary, if the practically applicable regeneration method of a filter fabric of the invention is employed for regeneration and reuse of a filter fabric which is used for collecting dioxin-containing dust, not only it is environmental-friendly in global environments but also it results in prevention of harmful substance accumulation in human body and saving of treatment cost and labor.

In this connection, mercury, cadmium, lead and the like exemplified as heavy metals contained in the harmful dust are also regarded as harmful substances whose accumulation in human body is a serious issue relevant to the treatment method and environmental preservation and if the practically applicable regeneration method of a filter fabric of the invention is employed for regeneration and reuse of a filter fabric bearing these heavy metals, it is environmental-friendly in global environments and results in prevention of harmful substance

accumulation in human body.

A filter fabric or a regenerated filter fabric of this embodiment includes at least a dust collection layer containing PTFE fibers as a main component. Since PTFE fibers are excellent in chemical resistance, heat resistance, electric charge retention property, and strength, they are suitable for a filtration and dust collection layer. On the other hand, since PTFE fibers have the same problem of disposition as dioxin that when they are incinerated, harmful gases including fluorine compounds, e.g. hydrofluoric acid and fluorohydrocarbons are evolved and thus it is especially desired to regenerate and reuse the PTFE fibers.

The filter fabric having the dust collection layer containing the PTFE fibers can be used as a filter fabric for a high temperature of 150°C or higher and accordingly it is made possible to use the filter fabric for high temperature dust collection, unlike a conventional filter fabric which is coated with a thermally fusible binder resin and thus impossible to be used for it.

The fibers for the dust collection layer may be formed from glass fibers, PPS, polyimide, meta-aramid besides the PTFE fibers or their mixtures with the PTFE fibers. Particularly, the fibers of the regenerated dust collection layer are preferable to consist of regenerated fibers as a main component and one or more kinds of auxiliary fibers for assisting the

functions of the filter fabric (strength, elongation, or filtering efficiency) mixed with the regenerated fibers.

The auxiliary fibers are preferable to be new (not used) fibers and specifically, PTFE fibers suitable for a regenerated filter fabric or inorganic fibers such as silica, alumina, and glass fibers are preferably used. Further, the auxiliary fibers are preferable to be long or thin as compared with other component fibers. In the regeneration process of a used filter fabric, the auxiliary fibers are added in "Step of mixing auxiliary fibers" described later.

(Example of regeneration method)

As shown in Fig. 1, a regeneration method of a filter fabric of this embodiment involves steps of (1) chemical agent addition treatment for adding a chemical agent during steady operation, startup (starting operation), or shutdown (stopping operation) of an incinerator in order to remove harmful dust components and prevent adhesion and formation of them; (2) water washing treatment for washing and drying the used filter fabric from which metals or the like are separated after being removed from a dust collecting apparatus; (3) fibrillation treatment for fibrillating the used filter fabric into each individual fibers; (4) powder dust separation treatment for separating powder dust adhering to the fibrillated fibers; (5) nonwoven treatment for producing a nonwoven fabric from the fibrillated fibers subjected to the powder dust separation treatment; (6) punching treatment

for fixing the fibers formed into the nonwoven fabric to a base cloth by a needle punch; and (7) finishing treatment for preventing the fibers from dropping off by reinforcing and finishing the surface of the nonwoven fabric subjected to the punching treatment. Hereinafter the respective treatment steps will be described respectively.

(1 chemical agent addition treatment)

The chemical agent addition treatment is treatment for adding a chemical agent to a filter fabric during operation of an incinerator or a dust collecting apparatus, that is, while the filter fabric is being used. Specifically, the treatment consists of steady operation treatment for spraying the chemical agent for preventing formation of harmful dust and removing the harmful dust during the steady operation of the incinerator, and startup and shutdown operation treatment for spraying a harmful dust decomposition and removal agent at the startup and shutdown time of the incinerator. Accordingly, the filter fabric can be used while the absolute number of harmful dust particles in dust-containing air being decreased and adhesion of the harmful dust to the filter fabric being inhibited.

In this embodiment, the above-mentioned chemical agent is for decomposing both dioxin and dioxin origin substances and in the used filter fabric subjected to the chemical agent addition treatment, the adhesion of harmful dust is inhibited: for example, in the case of dioxin, its adhesion is inhibited to the level



of 3 ng (nano-gram)-TEQ/g or less.

Additionally, the chemical agent addition treatment is treatment required in the case where harmful dust containing dioxin and dioxin origin substances is generated, and therefore if no harmful dust is generated, this treatment is not required.

The steady operation treatment is treatment for spraying a harmful dust formation prevention agent by a spray periodically to an area from a cooling tower to a dust collecting apparatus. Because of this treatment, the formation of harmful dust which is formed slightly and gradually during the operation of the incinerator is inhibited and the harmful dust is adsorbed and removed in the dust collection apparatus.

In the case where the harmful dust is gaseous and solid dioxin, the harmful dust formation prevention agent contains activated carbon and slaked lime for adsorbing gaseous or solid dioxin as main components and for example, US LIME CD (trade name), manufactured by UEDA LIME CO., LTD. may be used. Also, TAMAKARUKU (trade name) manufactured by YAKUSEN SEKKAI Co., Ltd. is usable. When the harmful dust formation prevention agent is sprayed, the agent prevents adhesion of solid dioxin, which is contained in harmful dust, to the filter fabric by forming a harmful dust removal layer with a thickness of several  $\mu\text{m}$  on the filter fabric in the dust collecting apparatus.

The startup and shutdown operation treatment is treatment for spraying a harmful dust decomposition and removal agent by

a spray to an area from the cooling tower to a flue and the dust collecting apparatus at the startup time and shutdown time of the incinerator. Accordingly, a harmful dust decomposition and removal layer is formed in the entire body of the main path of dust-containing air to decompose the harmful dust and its origin substances. Specifically, by spraying about  $300 \text{ mg/Nm}^3$  of the agent, high concentration dioxin and dioxin origin substance formed in the flue and the dust collecting apparatus are decomposed at the startup time and shutdown time of the incinerator of which atmosphere is  $300^\circ\text{C}$  or lower.

Herein, the startup time and shutdown time of the incinerator means a part of operating time of the incinerator and the dust collecting apparatus. Specifically, this means the time for inspection of apparatus generally conducted once every about 3 months in the case of relatively large scale incineration facilities and also the time when the incinerator and the dust collecting apparatus are stopped at every about 7 to 10 days interval in the case of relatively small incineration facilities.

The dioxin origin substances mean dioxin precursors such as chlorophenol and chlorobenzene. The dioxin precursors are substances causing secondary products of dioxin in the outside of the incinerator.

The harmful dust decomposition removal agent to be used may be ASHNITE MULTI A (trade name) manufactured by Kurita Water Industries Ltd. The agent decomposes dioxin contained in the

gaseous and solid harmful dust and also decomposes dioxin origin substances to prevent formation of harmful dust. Accordingly, the agent can prevent increase of the dioxin in dust-containing air and simultaneously decreases the concentration of dioxin and dioxin origin substances. Consequently, dioxin deposition and adhesion to the filter fabric can be prevented.

(2 water washing treatment)

The water washing treatment is treatment for immersing a used filter fabric in flowing water so as to wash out easily separable dust after the used filter fabric is removed from the dust collecting apparatus and metal or the like is separated from the filter fabric. It is preferable to add a surfactant to the flowing water for adsorbing and separating dust chemically. Specifically, the filter is washed with a double-shell rotary drum type water washing apparatus or the like and dried.

The used filter fabric means a filter fabric which loses the function as a filter fabric if it remains fixed in the dust collecting apparatus due to the continuous use of the filter fabric with fixing in the dust collecting apparatus. Specifically, the used filter fabric means a filter fabric which has been used for filtering and collecting dust of an incinerator flue gas while appropriately being back-washed with compressed air and accordingly contains solid dust deposited even in the inside. Further, the used filter fabric means a filter fabric whose airflow degree is lowered to  $1 \text{ cc/cm}^2/\text{sec}$  or lower or whose

pressure loss becomes 1800 Pa or higher during the operation and a clogging is occurred at least partially or a filter fabric whose fibers are visually found broken or decaying in the surface or the inside and thus which has a problem in the filtering efficiency. That the filter fabric has a problem in the filtering efficiency means that the powder leakage occurs at least partially and thus the dust concentration at the outlet is considerably decreased during operation and that at least a portion of the filter fabric rather much expanded due to a long time use is significantly parted from the filter fabric attachment means such as a shape retaining metal (a retainer), or that the twisted fibers of the filter fabric rather shrunk due to a long time use are loosened (untwisted) and torn out. A filter fabric becomes the used filter fabric after continuous use for about 5 months to 5 years in the case of common high temperature dust collection with a dust collecting apparatus and particularly in the case of dust collection of an incinerator flue gas from an incinerator, it becomes the used filter fabric after using for about 3 to 5 years.

The wet washing for such chemical separation has high washing efficiency as compared with that of backwashing carried out by blowing compressed air while the filter fabric being fixed in the dust collecting apparatus. This treatment is carried out before the fibrillation treatment described later, so that dust separation with high efficiency in the fibrillation

treatment can be achieved. However, since it is difficult to apply sufficient water pressure to the portions other than the surface layer of the filter fabric, it is impossible to completely wash out dust or the like adhering to the component fibers in the inside.

(3 fibrillation treatment)

The fibrillation treatment is treatment for fibrillating the used filter fabric into each individual fibers in order to separate the dust clogged among the fibers in the inside of the component fibers and simultaneously removing even the dust electrostatically attracted to the individual fibers by applying physical pressure and impacts and vibrations at the time of fibrillation. Accordingly, a highly powerful regenerated filter fabric can be obtained easily and economically and practical regeneration is made possible. In this embodiment, the fibrillation treatment is carried out by passing the used filter fabric through an automatic fibrillating apparatus.

The automatic fibrillating apparatus means a fibrillating apparatus for automatically carrying out fibrillation of fibers by motive power other than manual work and thus excludes fibrillation solely by manual. Specifically, feeding of the filter fabric into the fibrillating apparatus prior to fibrillation and fibrillating the fed filter fabric are continuously carried out by motive power other than a manual work, or by a combination of a manual work and motive power other

than the manual work. For example, the used filter fabric is repeatedly put into a dry type automatic fibrillating apparatus such as combing rolls until a bundle of fibers is untwisted so that fibrillated individual fibers with a fiber length of 10 to 50 mm, preferably 20 mm to 40 mm are obtained. Any kinds of rolls such as needle blade type rolls, garnet rolls, and others may be used for the combing rolls.

At the time of the fibrillation treatment, a piece of cloth as auxiliary fibers which are added in the auxiliary fiber addition step described later may be added to simultaneously carry out the fibrillation treatment and the auxiliary fiber addition step.

(4 powder dust separation treatment)

The powder dust separation treatment is for separating dust adhering to the individual fibers after the fibrillation using a conventionally known powder dust separation apparatus. As a conventionally known powder dust separation apparatus, there are Micron Separator (trademark) (MS-1) manufactured by HOSOKAWA MICRON Corporation; WOOL CLEANER manufactured by OSAKA KIKO Co., Ltd.; and Binder Remover manufactured by IKEGAMI KIKAI Co., Ltd. and in addition to dry type separation apparatuses such as punching metal separation and airflow separation, wet type separation apparatuses such as the water washing apparatus to be used for the above-mentioned water washing treatment can be employed. Since the powder dust separation is carried out after

the fibrillation, the powder dust adhering to the individual fiber elements can be separated with a high efficiency.

Accordingly, fine dust which is accumulated even in the inside of the filter fabric while being used and which cannot be removed by a conventional regeneration method such as backwashing or water washing can be separated. As another method, the powder dust separation treatment may be carried out by water washing.

(5 nonwoven treatment)

The nonwoven treatment involves an auxiliary fiber addition step for adding auxiliary fibers to a large number of fibrillated fibers and a lap-forming step for forming the individual fibers into a dust collection layer of the regenerated filter fabric.

The auxiliary fiber addition step is a step for adding fibers which are longer than the fibrillated individual fibers so as to strengthen the twisting of one fiber to another fiber making up the nonwoven fabric and therefore increase the strength and elongation of the regenerated dust collection layer. This step is optionally added depending on the intended purposes of the regenerated filter fabric. Specifically, auxiliary fibers with a fiber length of 50 to 70 mm and a diameter of 5 to 20  $\mu\text{m}$  are added evenly at a ratio of 20 to 70% by weight, preferably 30 to 60% by weight.

The material of the auxiliary fibers to be used in the embodiment are PTFE fibers same as those used for

pre-regeneration dust collection layer and new fibers which have not been used for filter fabric. Besides them, the auxiliary fibers may include fibers of other materials different from that of the dust collection layer as long as they are within the scope of the use purpose of the auxiliary fibers and for example, inorganic fibers (silica, alumina, glass fibers etc.) with a smaller fiber diameter than that of the PTFE fibers may be used. The auxiliary fiber addition step strengthens the twisting of the fibers of the regenerated dust collection layer. Further, by addition of the glass fibers, the electrostatic effect is increased to improve the dust collecting efficiency of the regenerated dust collection layer.

The fineness of the auxiliary fibers is in a range of 1 to 15 dtex, preferably 3 to 10 dtex. This is because the auxiliary fibers with a fineness lower than 1 dtex are scarcely available and the auxiliary fibers with a fineness of 15 dtex or higher increase the pressure loss. Addition of the auxiliary fibers with a small fiber diameter decreases the pressure loss because this makes the average fiber diameter of the entire dust collection layer to smaller.

The lap-formation step is a step for forming the fibrillated fabrics, which is mixed with the auxiliary fibers if necessary, into a desired shape to make the dust collection layer of the regenerated filter fabric. The desired form means such shapes which are workable as the dust collection layer when



being placed, for example, a plate-like, a web-like, and a sheet-like shapes. Conventional forming method such as a card forming system by compressing the fibers in sheet-like form by compression rolls, an air-layer system for forming a sheet by sucking air, as well as conventional forming method such as paper making system can be employed. An oil agent or the like may be added to suppress static electricity and friction at the time of the formation.

(6 punching treatment)

The punching treatment is treatment for fixing the dust collection layer made up of the formed fiber group with a base cloth by needle punching. The base cloth is for increasing the strength and elongation of the dust collection layer by being placed along the dust collection layer. Alternatively, the punching treatment is treatment for needle punching only the dust collection layer made up of the formed fiber group without attaching the base cloth or the like if appropriate. The needle punching strengthens the twisting of one fiber to another fiber making up the fiber group. In the case where the punching treatment is carried out with attaching the base cloth, the strength and the elongation are remarkably improved.

The base cloth is preferable to be made of PTFE, the same material as that of the dust collection layer. If it is made of PTFE, the filter fabric to be obtained is provided with excellent heat resistance, chemical resistance, and high purity

even after regeneration. If a different material or a material mixed with a different material is used, the filter fabric can be economical while having a needed strength. The material is preferable to have a strength of 100 N/cm width or higher and an elongation of 40% or lower.

(7 finishing treatment)

The finishing treatment is treatment for fixing the shape of the regenerated filter fabric consisting of the nonwoven fabric and may be optionally carried out based on the necessity. Specifically, the treatment includes resin finishing step for applying resin on the surface of the regenerated filter fabric and heat treatment step in which the regenerated filter fabric is treated with heat.

The resin processing step is an optional step of preventing the individual fibers from dropping off the regenerated dust collection layer and becoming dust by applying resin on the surface of the formed dust collection layer. The application of resin may be conducted by conventional means such as dipping in a liquid phase resin, spray coating of the resin, or coating.

The heat treatment step is a step for stabilizing the shape of the regenerated filter fabric by heat treatment at 200 to 330°C and this is an optional step carried out depending on the intended use such as high temperature application. Accordingly, breakage of fibers can be prevented even in the case that the regenerated filter fabric is used in a high temperature of 150°C

or more.

(Specification of obtained product)

Hereinafter, a regenerated filter fabric of the present invention obtained by the above-mentioned regenerating method is specified. The regenerated filter fabric of the present invention includes at least a dust collection layer made up of the fibrillated fibers obtained by fibrillating the used filter fabric. Also, the regenerated filter fabric may include at least the dust collection layer made up of the fibrillated fibers obtained by fibrillating the used filter fabric and a base cloth on which the dust collection layer is fixed.

The used filter fabric contains at least PTFE fibers. The PTFE fibers are preferable to be a main component of the used filter fabric. Further, the used filter fabric is preferable to contain at least inorganic fibers in addition to the PTFE fibers.

The dust collection layer is preferable to be made up of the nonwoven fabric produced from the fibers which makes up the dust collection layer. The fibers making up the dust collection layer itself contains mainly the fibrillated fibers obtained by fibrillating the used filter fabric. The fibers making up the dust collection layer may contain auxiliary fibers added to the fibrillated fibers.

The base cloth is fixed to the dust collection layer if necessary to reliably provide the shape retention, the strength

and the elongation of the dust collection layer. The base cloth is not essential if the dust collection layer is given the needed strength by adding the auxiliary fibers to the dust collection layer or the nonwoven treatment of the fibers making up the dust collection layer.

That is, the regenerated filter fabric provided with a sufficiently high strength may include, for example, the following two kinds of filter fabrics: the regenerated filter fabric including the dust collection layer made up of a nonwoven fabric produced from the mixed fibers of the fibers obtained by fibrillating the used filter fabric and the auxiliary fibers, and the regenerated filter fabric made up of a nonwoven fabric produced from the fibers obtained by fibrillating the used filter fabric.

Further, the filter fabric provided with a desirable strength may be, for example, a regenerated filter fabric including the dust collection layer formed by using fibers obtained by fibrillating a used filter fabric and mixed with the auxiliary fibers and the base cloth for fixing the dust collection layer.

Since the regenerated filter fabric of the invention is once fibrillated, the fibers are fibrillated approximately evenly not only in the surface layer of the dust collection layer but also its entire area to the thickness direction and therefore, a relatively thick fibrillated layer is formed.

Herein, the approximately even fibrillation means that 10 or less branched fibers are found existing per each pre-branched fiber trunk by eye observation, as shown in Fig. 2.

Fig. 2 is an electron microscopic photograph with a magnification of 1000 times showing the fibers fibrillated by the fibrillation treatment in the regeneration method of the invention. As a comparative reference, Fig. 3 is an electron microscopic photograph with a magnification of 1000 times showing the fibers which are not subjected to the fibrillation treatment and thus not fibrillated.

The regenerated filter fabric of the invention is obtained by regenerating a filter fabric bearing dust owing to its use and dust slightly remains even by the regenerating method of the present invention. Specifically, in the dust collection layer of the regenerated filter fabric, dust in a concentration of about  $1 \text{ g/m}^2$  or lower, at lowest several  $\text{mg/m}^2$ , remains. Even if dust remains, as long as the initial airflow volume of the regenerated filter fabric is same as that of a new filter fabric, there is no problem for practical use. Further, even though the dust tends to be easily accumulated inside of the regenerated filter fabric during long use and the airflow volume is slightly increased owing to the remaining dust in the initial period, as long as the initial airflow volume of the regenerated filter fabric is same as that of a new filter fabric, there is no problem

for practical use. As shown in test results in Table 1, 135 Pa after 8 hour use is a satisfactory value for practical use.

With respect to the regenerated filter fabric of the invention, the fibers obtained by fibrillation have a fiber length of 20 to 40 mm and at longest 50 mm. This is a mechanical constraint to pass the fibers through an automatic fibrillating apparatus.

The density (METSUKE) of the filter fabric (METSUKE of the entire filter fabric including the base cloth and the dust collection layer) is about 300 to 1000 g/m<sup>2</sup> (it is 400 g/m<sup>2</sup> or higher particularly for the filter fabric having the base cloth) and preferably 600 to 800 g/m<sup>2</sup>.

With the regenerated filter fabric of this embodiment, the fibers are approximately evenly fibrillated as shown in Fig. 2 by mechanical fibrillation with an automatic fibrillating apparatus. The fibrillated fibers are twisted to form a nonwoven fabric, so that a dust collection efficiency can be as high as desired even if the density is low, about 400 g/m<sup>2</sup>. Accordingly, many regenerated fibers can be obtained from a small amount of original fibers and the regenerated filter fabric is remarkably economical owing to the cost down of the raw material.

On the other hand, if the density of the dust collection layer is about 500 g/m<sup>2</sup> or higher, more preferably 700 g/m<sup>2</sup> or higher, regenerated fibers with a high density can be obtained from the evenly fibrillated and highly dense fibers and therefore

it is made possible to collect dust with a very small particle size, which has been impossible to be collected conventionally. Or, even in the case the thickness of the dust collection layer is relatively thin, the pressure loss can be suppressed and also high dust collection efficiency can be achieved. Consequently, the regenerated filter fabric is economical.

Further, the fibrillated portions of the fibrillated fiber are extremely thin as compared with the main body of the fibrillated fiber. Therefore, the pressure loss in the fibrillated portions becomes insignificant within a measurement error and the dust collection efficiency is increased as compared with that of a dust collection layer formed by only non-fibrillated fibers.

The regenerated filter fabric of this embodiment contains fibers approximately evenly fibrillated not only in the surface layer of the dust collection layer but also in its entire area to the thickness direction, so that no boundary layer is formed in the front and back fibrillated fiber layers and thus decrease of the dust collection efficiency owing to inertia of air passing through different layers between the front and rear fibrillated fiber layers is not caused. Accordingly, the regenerated filter fabric can collect dust reliably and have an excellent dust collecting efficiency.

The invention has been described with reference to specific constitutions, apparatuses, and methods, and the invention is

not limited by the above-mentioned embodiments. For example, chemical agent addition treatment, water washing treatment, powder dust separation treatment, punching treatment, and the finishing treatment in the above-mentioned embodiments may properly be selected depending on the intended use of the filter fabric and included in the respective treatment steps of the regeneration method if needed as long as the regeneration method involves at least fibrillation treatment (preferably fibrillation treatment and nonwoven treatment). Also, similarly, other treatments may be involved depending on the intended use of the regenerated filter fabric. Various modifications and specific process combinations may occur in the art without departing from the true spirit and scope of the invention.

(Comparative Test)

The following comparative tests for Example 1 of the invention were carried out. The products for comparison were a new filter fabric and a filter fabric obtained by only water washing treatment in the regeneration method of Example 1.

Example 1

As Example 1 of the invention to be used for the comparative tests was employed a filter fabric, BF-800 manufactured by FUJI Corporation, having a dust collection layer and a base cloth both made of PTFE fibers and being used for a TQPJ type filtering



dust collection apparatus manufactured by HOSOKAWA MICRON Corporation for 6 months; then the filter fabric was washed with water by a washing machine and dried (water washing treatment); the filter fabric was fibrillated into fibers with a fiber length of 40 mm or shorter by a dry type automatic fibrillating apparatus manufactured by FUJI Corporation at a rotation speed of 500 rpm (fibrillation treatment); dust was separated from the fibrillated fibers by Micron Separator (MS-1) manufactured by HOSOKAWA MICRON Corporation with a rotor rotation speed of 2100 rpm (powder dust separation treatment); the fibers were lap-formed into a nonwoven fabric by a commercialized roller card (nonwoven treatment); further the nonwoven fabric was fixed with a base cloth having a strength of 750 N/5 cm width and an elongation of 25% by needle punching (punching treatment); and finally the nonwoven fabric with the base cloth was formed into a filter fabric with a thickness of 1.3 mm.

(Comparative Example 1 (new filter fabric))

BF-800 manufactured by FUJI Corporation was used as a new filter fabric of Comparative Example 1.

(Comparative Example 2 (regenerated filter fabric by water washing method))

As a filter fabric of Comparative Example 2 was used a filter fabric regenerated only by water washing treatment and not subjected to the fibrillation treatment, the powder dust separation treatment, the nonwoven treatment, the punching

treatment, and the finishing treatment as described above.

(Contents and measurement results of comparative tests)

According to Germany VDI 3926, the initial airflow degree, the final airflow degree, and the outlet dust concentration were measured as the comparative tests. The measurement conditions were as a filtration speed of 3.0 m/min. and an inlet dust concentration of 5.0 g/m<sup>3</sup> and as dust, JIS 10 type (fly ash) was used. When the airflow degree reached 1000 Pa, backwashing by blowing compressed air was properly carried out and the operation was continued for 8 hours for test duration.

The initial airflow degree means the airflow degree immediately after starting the test. The final airflow degree means the airflow degree after 8 hours test. The outlet dust concentration is the value calculated by dividing the total dust amount obtained at the outlet by the operation for 8 hours by total air quantity blown during the 8 hours operation. The results are shown in Table 1.

Table 1

Measurement value [unit]	Example 1 (regenerated filter fabric of the invention)	Comparative Example 1 (new filter fabric)	Comparative Example 2 (regenerated filter fabric obtained by water washing method)
Initial airflow degree [Pa]	70	70	106
Final airflow degree [Pa]	135	122	302
Outlet dust concentration [mg/m <sup>3</sup> ]	0.812	1.173	2.15

According to the measurement results shown in Table 1, the regenerated filter fabric of Example 1 according to the invention had an initial airflow degree of 70 Pa, which is the same pressure loss as that of a new filter fabric (70 Pa). It implies that dust was removed to the extent approximately same to that of a new filter fabric and the regenerated filter fabric obtained is practically usable according to the regenerating method of the invention. Also, much more dust was removed as compared with the result of the regenerated filter fabric (106 Pa) obtained only by water washing in Comparative Example.

The pressure loss after 8 hours use was 135 Pa, which was slightly numerically high as compared with that (122 Pa) of the new filter fabric, however this value does not mean the regenerated filter fabric tends to be easily clogged in practically use, and the regenerated filter fabric have approximately same lifetime as that of the new filter fabric. As compared with the regenerated filter fabric of Comparative Example (302 Pa), the clogging problem hardly occurs in the regenerated filter fabric of Example 1 of the present invention and it has a long life as a regenerated filter fabric.

According to the measurement results shown in Table 1, the regenerated filter fabric of Example 1 had an outlet dust concentration of  $0.812 \text{ mg/m}^3$ , showing a higher dust collecting efficiency than not only that ( $2.15 \text{ mg/m}^3$ ) of Comparative Example

but also that (1.173 mg/m<sup>3</sup>) of the new filter fabric. It is supposed to be because the fibers are fibrillated by the fibrillation treatment as shown in Fig. 2.

The filter fabric regeneration method and the regenerated filter fabric of the invention are applicable, for example, for a filtration type dust collection apparatus in waste incineration facilities. Additionally, they can be applicable to various kinds of filtration dust collection in a crusher, a classifier, a drier, a coating booth, an asphalt plant, a building, and various kinds of furnaces as well as for pneumatic transportation and powder production.